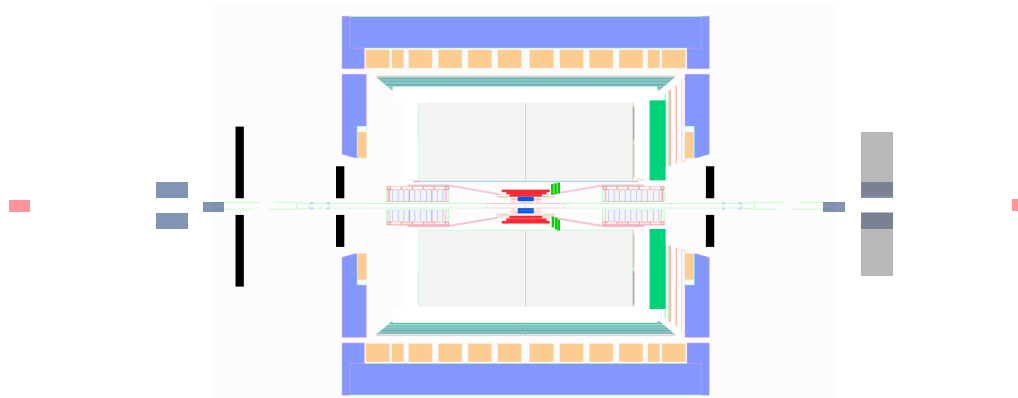


STAR detector upgrades in relation to RHIC SPIN program

Bernd Surrow
MIT



Main Assumptions:

- The RHIC Spin Collaboration will write a report which:
 - Describes the full spin program,
 - provides context of beam and physics achievements and
 - lists needs for future detection capabilities and instrumentation..

- The 5 and 10 week scenario's will enter the document:
 - Near the end to indicate their impact,
 - i.e. not at as early constraints on the spin program!

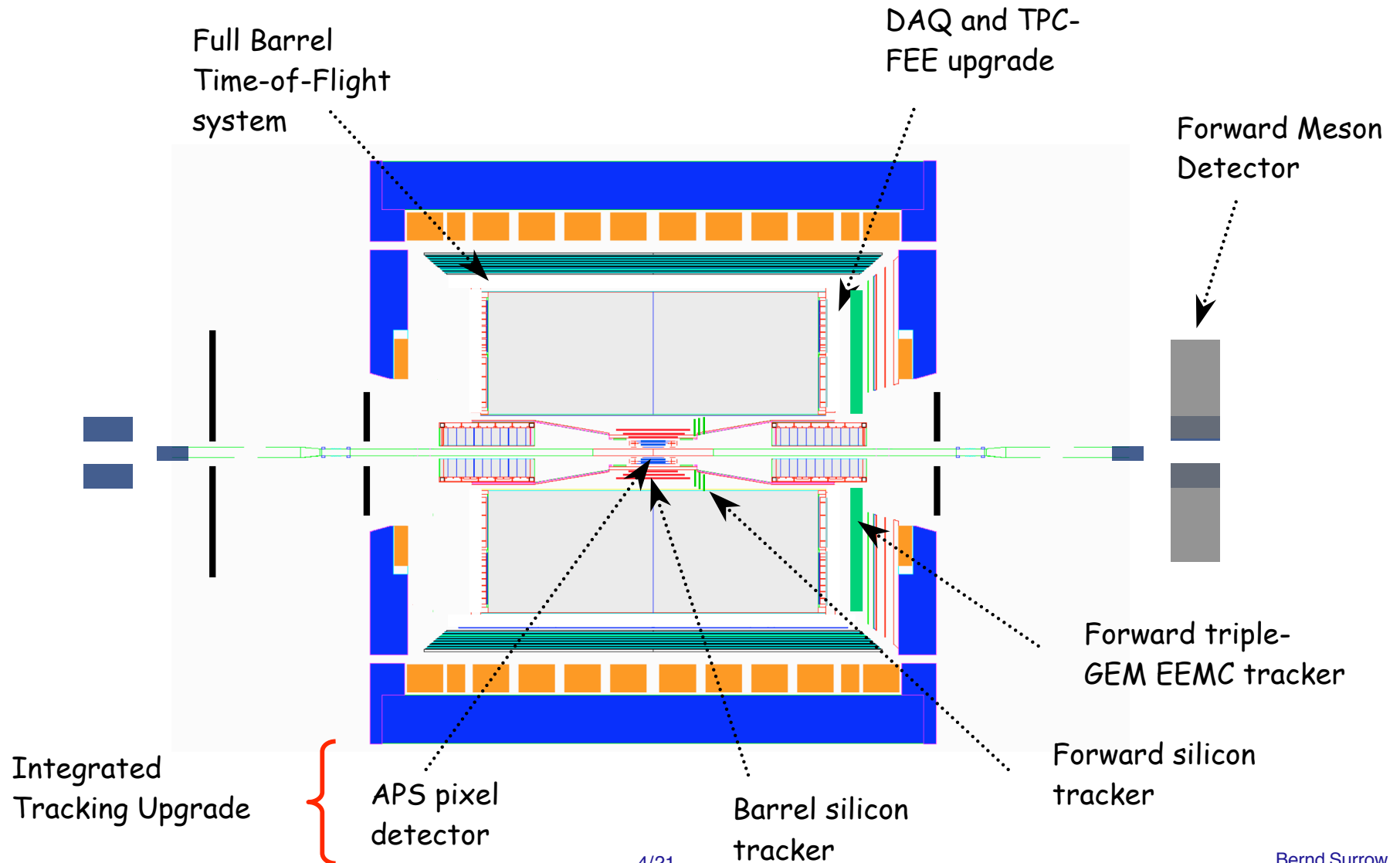
STAR detector upgrade program

■ Requirements on the STAR detector upgrade

- **Particle identification ($-1 < |\eta| < 1$):** Full acceptance TOF barrel system to extend particle identification capabilities
- **High rate TPC front-end electronics (FEE) readout and DAQ upgrade:** Allow for maximal utilization of high luminosity RHIC operation (AuAu/pp)
- **Inner tracker ($-1 < |\eta| < 1$):** Enhanced inner, high-rate tracking capabilities for heavy quark identification (charm/beauty) at mid-rapidity based on a precision micro-vertex detector
- **Endcap tracker ($1 < |\eta| < 2$):** Improved forward, high-rate tracking capability to enable reliable charge sign discrimination for W boson decays
- **Forward calorimetry upgrade ($2 < \eta < 4$):** Enhanced capabilities to measure forward produced mesons

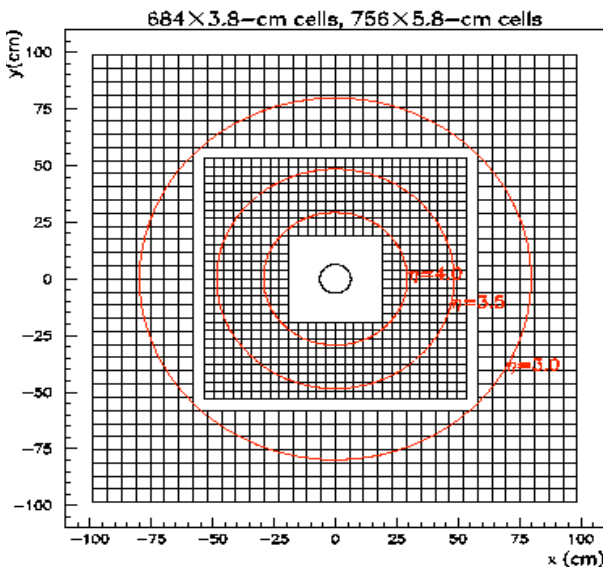
STAR upgrade program

■ Overview

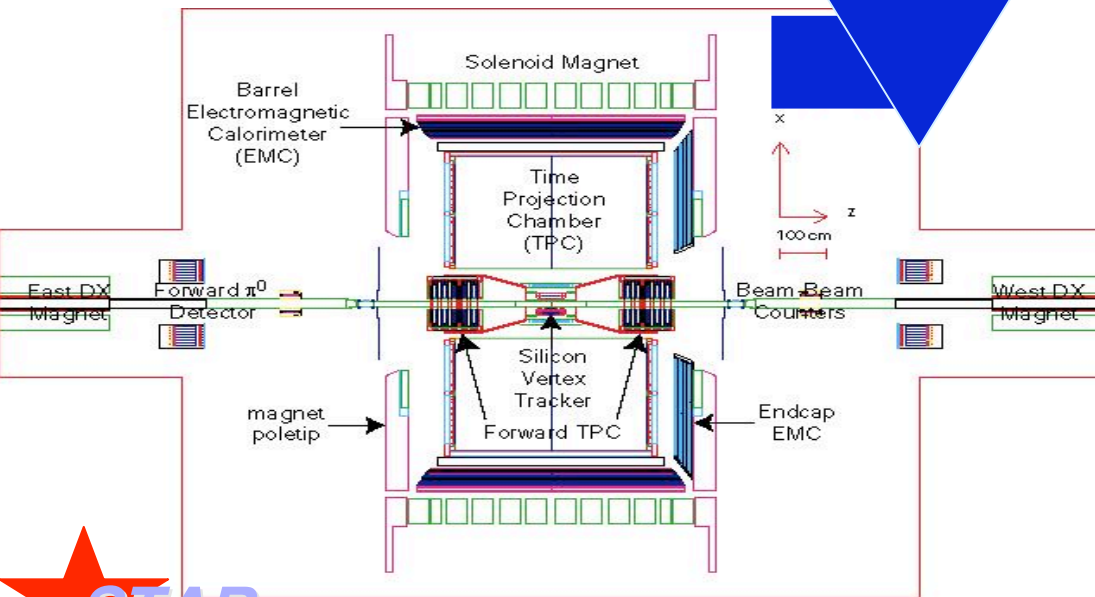


Forward Meson Spectrometer

Conceptual Design



FMS is a 2m×2m EM calorimeter built from existing lead-glass cells to replace the FPD west of STAR

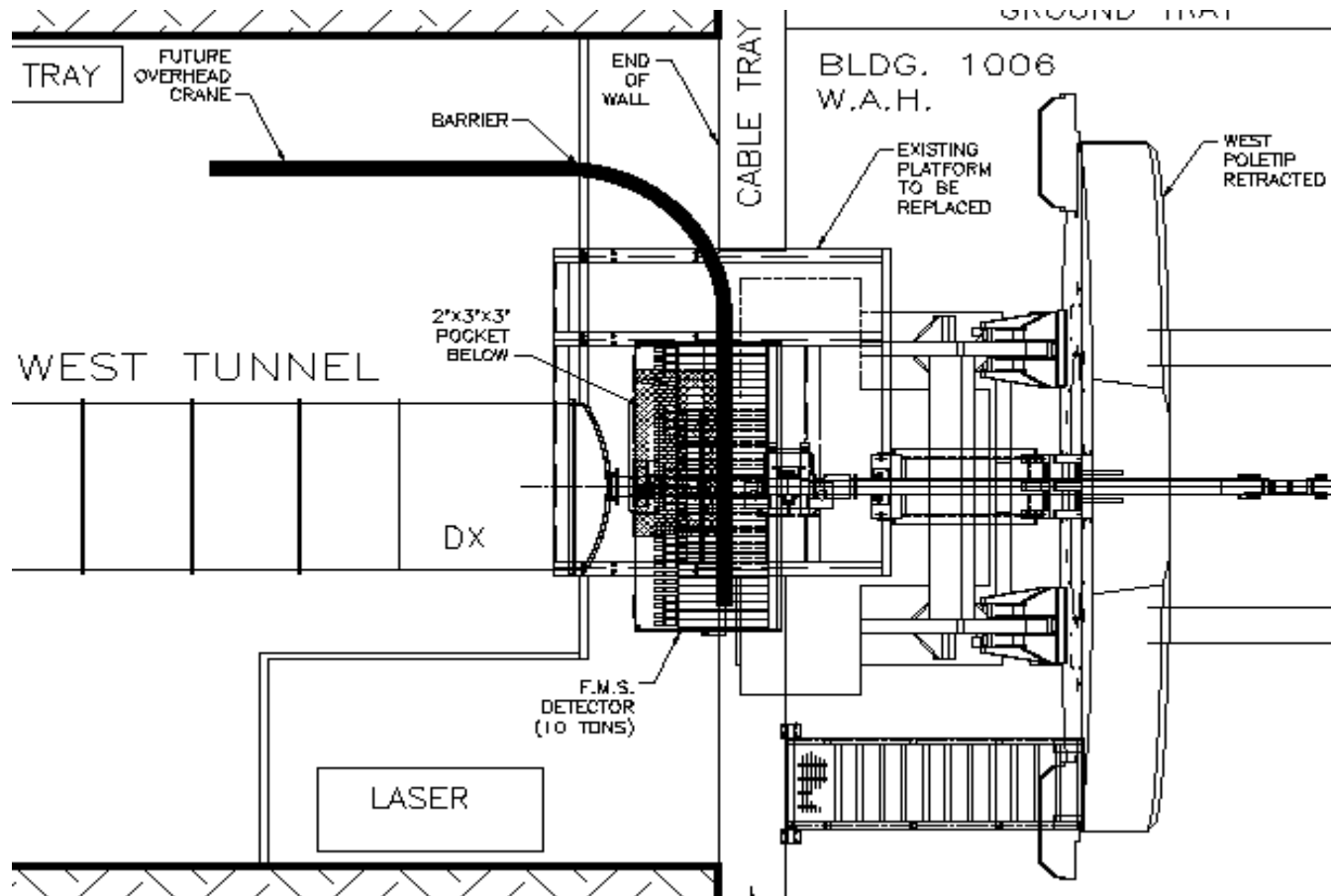


Physics Motivations:

- probe gluon saturation in $p(d)+A$ collisions via...
 - large rapidity particle production ($\pi^0, \eta, \omega, \eta', \gamma, K^0, \dots$) detected through all γ decays.
 - forward di-jet surrogates ($\pi^0-\pi^0$) probes gluons with smallest Bjorken- x in Au nucleus
 - di-jets with large rapidity interval (Mueller-Navelet jets)
- disentangling dynamical origins of large x_F analyzing power in $p_{\uparrow}+p$ collisions.
- longitudinal spin asymmetries for $\pi^0-\pi^0$ and $\gamma-\pi^0$ rapidity correlations

Forward Meson Spectrometer

Cost and Timetable



- built from existing lead glass cells from IHEP, Protvino and FNAL
- \$0.8M proposal by Penn State University to FY05 NSF-MRI solicitation for high voltage, readout electronics and mechanical realization in January, 2005.
- planned implementation in STAR by October, 2006

STAR tracking upgrade: Physics, status and timeline

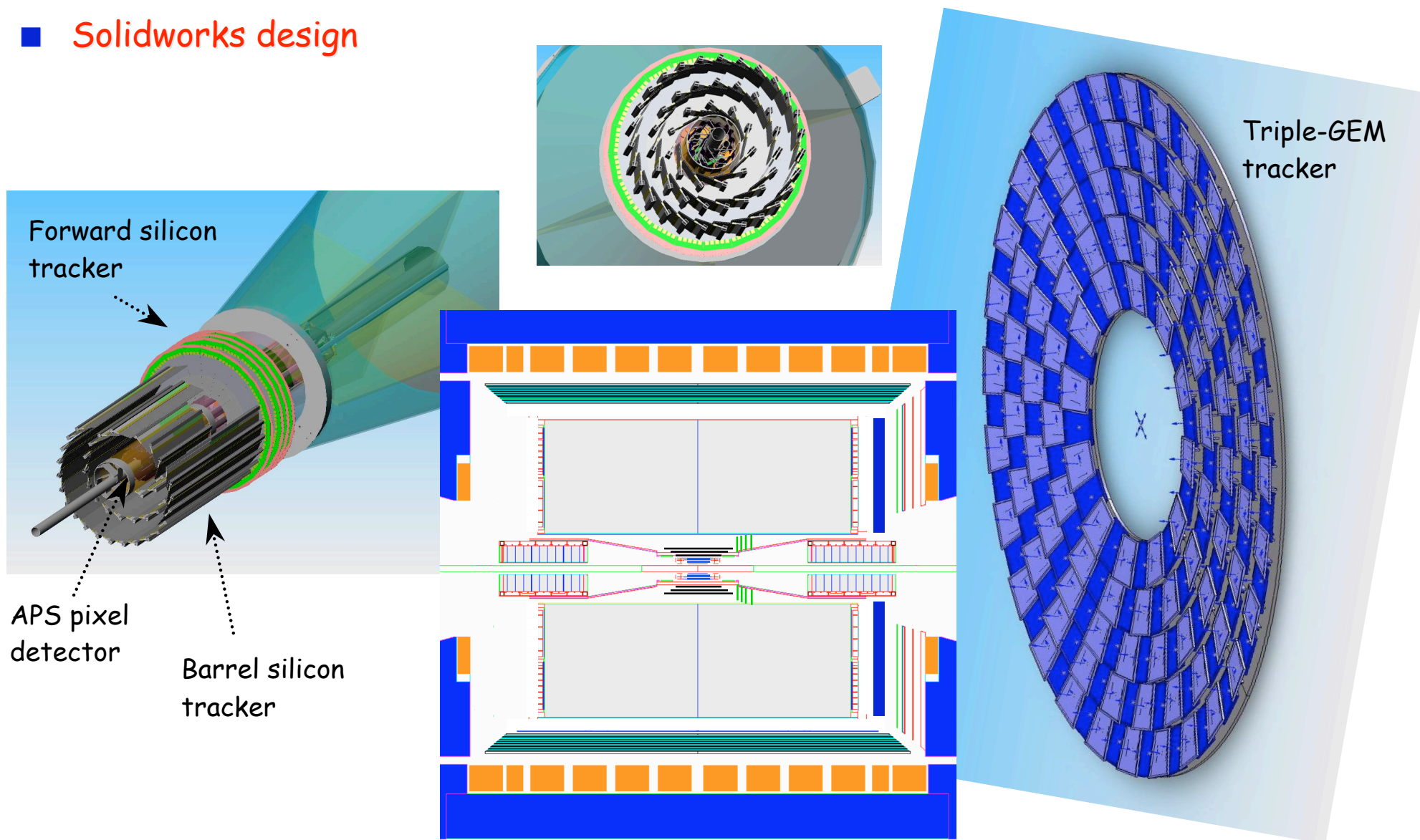
■ Physics, status and timeline

- The study of heavy flavors and W production: Upgrade of the STAR inner/forward tracking system
- Simulation work and design of detector layout based on silicon and triple-GEM technology (On-going R&D and prototyping effort) started
- Integrated tracking design of a new inner and forward STAR tracking system mandatory
- Staging of tracking upgrade in accordance with readiness of detector technology and beam development:
- Possible scenario:
 - Stage 1: Installation of STAR Micro-Vertex Detector together with a minimal new barrel tracking detector based on silicon technology ($-1 < \eta < 1$) (Heavy Flavor Physics)
 - Proposal APS Heavy Flavor Tracker early CY05
 - Proposal Barrel after FY05 run
 - Installation of new inner tracking system by summer 2008 (FY09 run)
 - Stage 2: Upgrade of the forward tracking system ($1 < \eta < 2$) (W physics)
 - Proposal after FY06 run
 - Installation of forward system by summer 2009 (FY10 run)
- Dedicated time for machine development with polarized protons to achieve high luminosity and high polarization is vital for the success of this novel program!

Documented
in STAR
decadal plan
and
AGS/RHIC
PAC

STAR tracking upgrade: Conceptual layout

■ Solidworks design



Comments on STAR tracking upgrade

- STAR tracking upgrade in RHIC SPIN document:

- Not yet a full DOE proposal!
- Plans and work in progress!

- Relation to other DOE proposals:

- ToF
- APS Heavy Flavor Tracker
- DAQ upgrade

- Communication to DOE Nuclear Physics:

- Funding profile and sources:

STAR tracking upgrade - Heavy flavor production

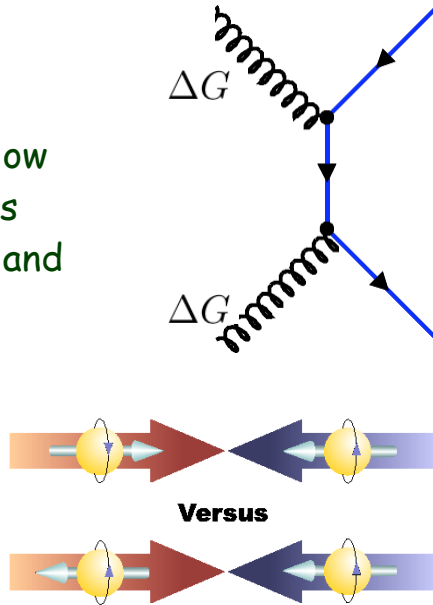
■ STAR RHIC-SPIN program

- Comprehensive study of the spin structure and dynamics of the proton, in particular the nature of the proton sea, using polarized protons: "RHIC SPIN Baseline program" (DOE review, June 2004)
 - Gluon contribution to the proton spin using various probes involving:
 - Final-state jets such as inclusive jet production and di-jet production (Short-term)
 - Inclusive π^0 production (Short-term)
 - Prompt photon production (Long-term)
 - Heavy-Flavor production (Long-term)
 - Flavor decomposition of quark and anti-quark polarization in W production (Long-term)

■ Heavy flavor production

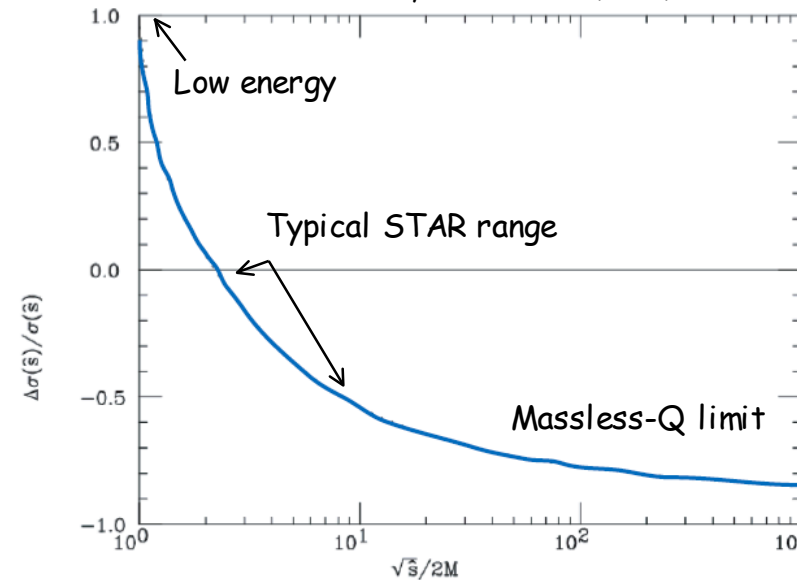
- Unique test of partonic a_{LL}
- Sensitive to gluon helicity with low background from quark helicities
- NLO formalism available (Bojak and Stratmann)

$$A_{LL} = \frac{(\sigma_{++} + \sigma_{--}) - (\sigma_{+-} + \sigma_{-+})}{(\sigma_{++} + \sigma_{--}) + (\sigma_{+-} + \sigma_{-+})}$$



10/21

M. Karliner and R.W. Robnett,
Phys. Lett. B324 (1994) 209.

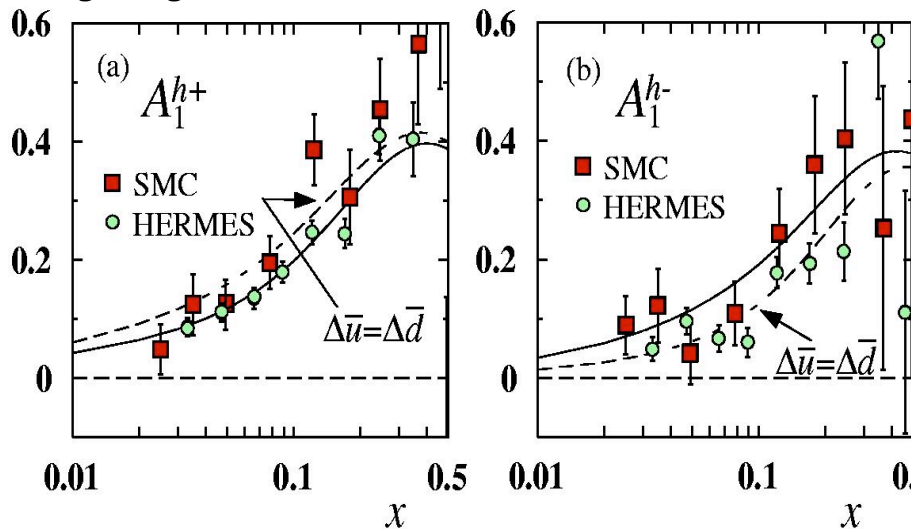


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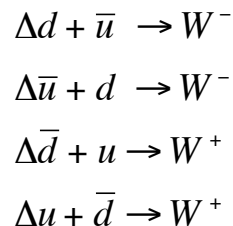
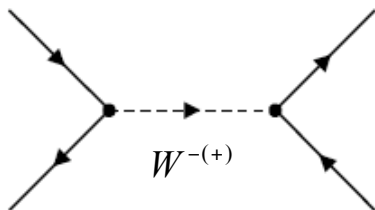
STAR tracking upgrade - W production

Flavor decomposition of quark and anti-quark polarization

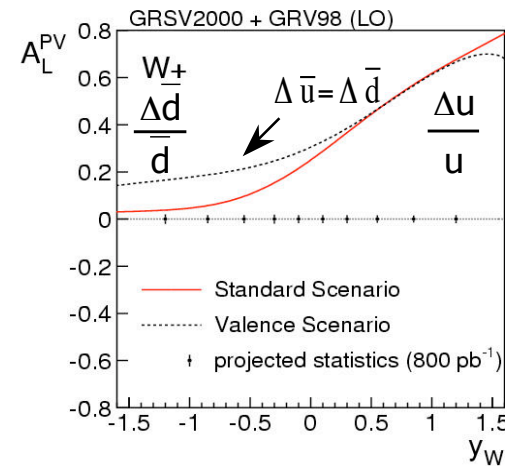
- Semi-inclusive DIS - sensitivity reduced by fragmentation functions and e_q^2 weighting
B. Dressler, Eur. Phys. J. C14 (2000) 147.



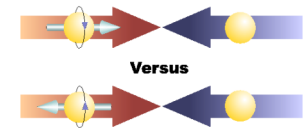
- W^\pm production in pp collisions forms the best means to probe the flavor structure of the proton sea



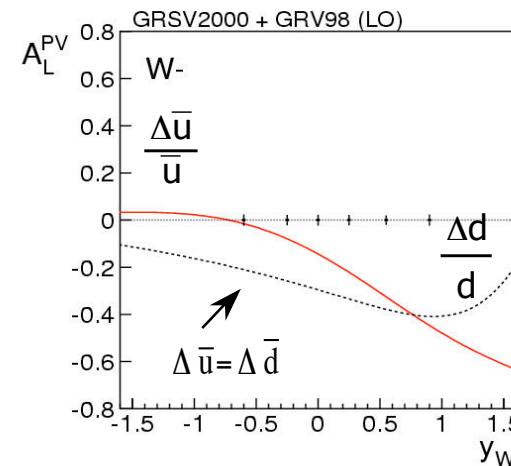
- Parity violating single-spin asymmetries at RHIC provide access to the quark flavor structure of the proton spin:



$$\begin{aligned} A_L^{PV(W^+)}(\bar{p}p) &\rightarrow \Delta u/u \\ A_L^{PV(W^+)}(p\bar{p}) &\rightarrow \Delta \bar{d}/\bar{d} \end{aligned}$$



$$A_L^{PV} = \frac{\sigma_+ - \sigma_-}{\sigma_+ + \sigma_-}$$



$$\begin{aligned} A_L^{PV(W^-)}(\bar{p}p) &\rightarrow \Delta d/d \\ A_L^{PV(W^-)}(p\bar{p}) &\rightarrow \Delta \bar{u}/\bar{u} \end{aligned}$$

J. Koryluk

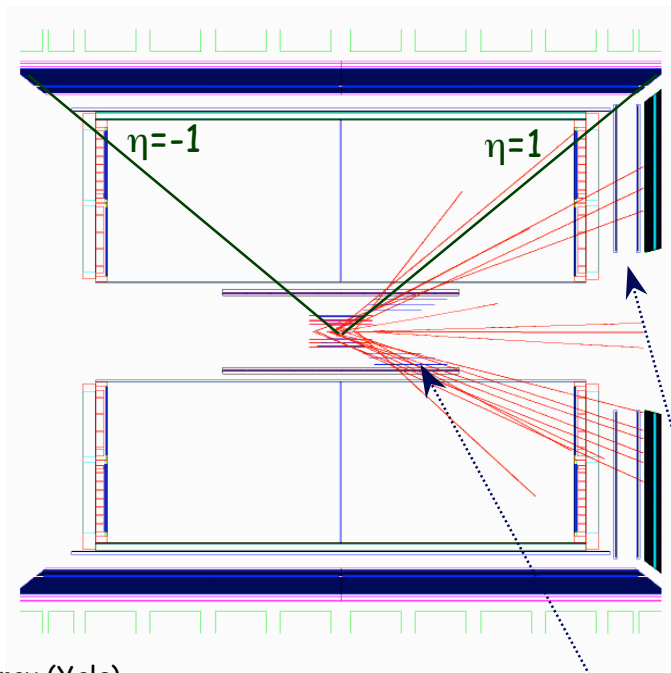
Bernd Surrow

STAR tracking upgrade - Forward tracking

■ Simulated forward p_T resolution ($1 < \eta < 2$)

● Forward p_T reconstruction: π^-

- True $p_T = 30 \text{ GeV}$
- Range in η : $1 < \eta < 2$

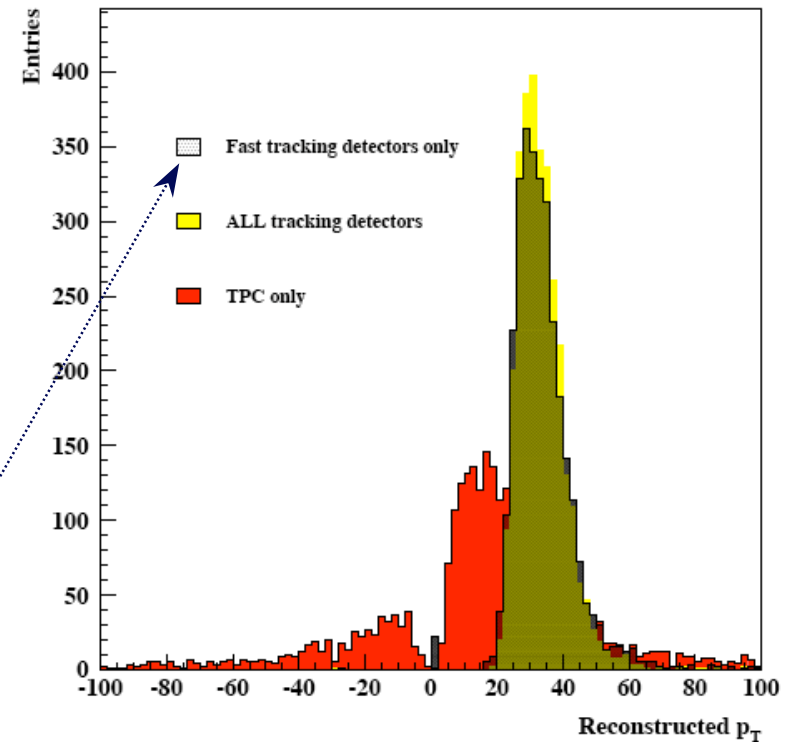


N. Smirnov (Yale)

● Simulated fast tracking configuration:

- Inner (fast) configuration: 3 silicon layers
- Outer (fast) configuration: 2 triple GEM layers

● Reconstructed p_T for various detector configurations:



STAR tracking upgrade

Integrated tracking approach of pixel upgrade and inner silicon upgrade in combination with forward GEM tracker!

STAR tracking upgrade - Organization matters

■ Goal of STAR tracking upgrade working group:

- ❑ Work out the case for a proposal towards an upgrade of the STAR inner ($-1 < \eta < 1$) and forward ($1 < \eta < 2$) tracking system which is required for the study of heavy flavor (AuAu/pp) and W production (pp)
 - W physics case: Flavor decomposition of quark/anti-quark polarization
 - Heavy flavor spin case (Strong dependence of partonic asymmetry on heavy quark mass- study of heavy flavor tagged jets): STAR Heavy flavor program driven by STAR's relativistic heavy-ion program
 - Integrated tracking design of a new inner and forward STAR tracking system is mandatory
 - Staging of tracking upgrade in accordance with readiness of detector technology and beam development
- ❑ Set-up of simulation tools, physics simulation studies and R&D work on triple-GEM technology has been started
- ❑ Participation so far from: ANL, BNL, IUCF, LBL, MIT, Yale, Zagreb,...
 - Graduate students/Postdocs: 3
 - Staff physicists/faculty: 15
 - Engineers/technicians: 2
- ❑ Convenors: Ernst Sichtermann (LBL) and B.S. (MIT)
- ❑ Steering committee: G. v. Nieuwenhuizen (MIT), N. Smirnov (Yale), S. Vigdor (IUCF), H. Wieman (LBL)

STAR tracking upgrade - Heavy flavor case

■ Remarks on the physics case (1)

- AuAu heavy-flavor physics drives the **STAR inner tracking upgrade**
 - Pixel detector proposal which requires a new pointing device (STAR SVT review)
 - Potential heavy flavor spin physics case (gluon polarization) in polarized pp collisions
 - Requirements:
 - Secondary vertex reconstruction capabilities for central region ($-1 < \eta < 1$) in combination with the APS Heavy Flavor Tracker
 - Intrinsically fast detector / readout system
 - To be defined: Number of silicon barrel layers at what radius? Resolution? Readout speed? Occupancy?

STAR tracking upgrade - W physics case

■ Remarks on the physics case (2)

- Study of flavor decomposition drives an upgrade of the **STAR forward tracking system**
 - Endcap calorimeter in combination with a new proposal towards a forward tracking system
 - Complication in STAR with TPC: Tracking/Charge discrimination for high energy leptons break down in the forward direction
 - Welcome ideas for use in Heavy Ion running,
 - Requirements:
 - e^-/e^+ charge sign discrimination in forward direction ($1 < \eta < 2$) (Sagitta $\sim 2.5\text{mm}$ for high p_T $\sim 30\text{GeV}$ tracks)
 - Intrinsically fast detector / readout system
 - To be defined: Number of silicon disks and location? Resolution? Impact of dead material in front of EEMC
- For both upgrades: Integrated mechanical design: **Integrated Tracking Upgrade**

STAR tracking upgrade - Design

■ General considerations

- Start from the beginning with an **integrated tracking design** approach which is based on:
 - ❑ **Integrated mechanical design** for the APS Heavy Flavor Tracker, barrel layers and forward disks
 - ❑ Design which is reflected by many **silicon based inner tracking systems** at **collider detectors** such as: CDF/DO (Tevatron), ZEUS/H1 (HERA) and ATLAS/CMS (LHC)
 - ❑ **First setup**: APS Heavy Flavor Tracker and minimal barrel system
 - ❑ **Flexibility** to **upgrade inner-forward system** and **inner-barrel system** at a later stage
 - ❑ Assumption: TPC stays as such, FTPC is phased out and DAQ/FEE upgrade is completed
- Rely as much as possible on existing well established technology:
 - ❑ Detector technology (Conservative choice: Conventional silicon strip and triple-GEM technology)
 - ❑ Readout systems (APV25-S1)
- Report towards a full proposal to document the conceptual layout of an integrated tracker for STAR under preparation:
 - ❑ Physics motivation
 - ❑ Conceptual layout and technical realization
 - ❑ Timeline and Manpower
 - ❑ Infrastructure
 - ❑ Cost estimate
- Profit from potential resources at **existing STAR** institutions in terms of **man-power** and **infra-structure**

STAR tracking upgrade: Simulation status

■ Overall status of simulation

● Fast simulation

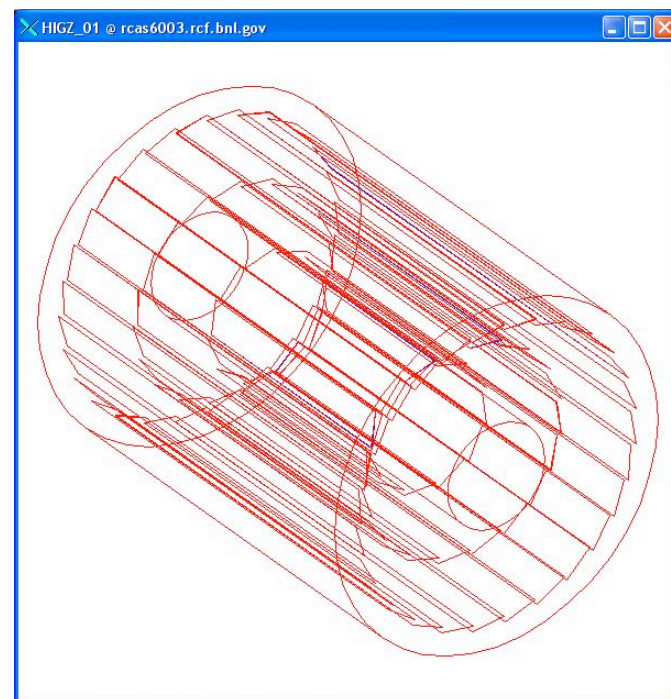
- ✓ PYTHIA input
- ✓ Poor man's "geant"
- ❑ Study detector number, placement, resolution, etc.

● Develop basic track reconstruction tools:

- ✓ "standard" helix fit
- ✓ First application of standard helix fit to W decay electrons
- ❑ Full simulations (W +background)
- ❑ Heavy flavor

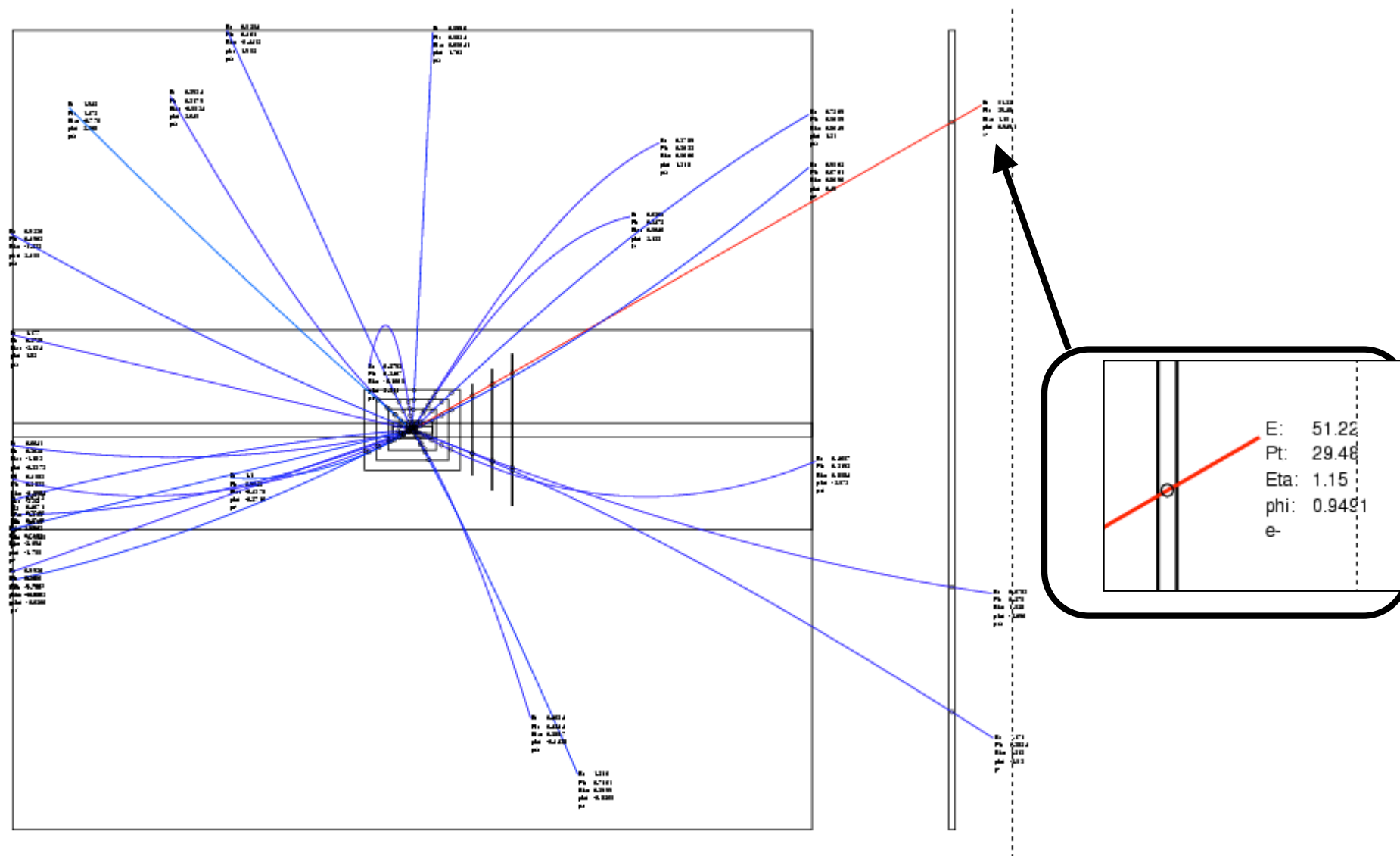
● Import design in *GSTAR*, ITTF:

- ✓ Full GEANT3 model (barrel/forward disks)
- ✓ Strip simulator
- ✓ Detector geometry in ITTF (New STAR track reconstruction)
- ✓ ITTF tracking in barrel region (Au-Au simulations)
- ❑ GEM tracker in *GSTAR*
- ❑ Forward ITTF tracking



STAR tracking upgrade: Simulation status

■ Fast simulator setup (Y-Z view)



STAR tracking upgrade: R&D status

■ Status of triple GEM R&D effort

- Design of at least three triple-GEM chambers to be installed and tested at STAR under beam conditions:

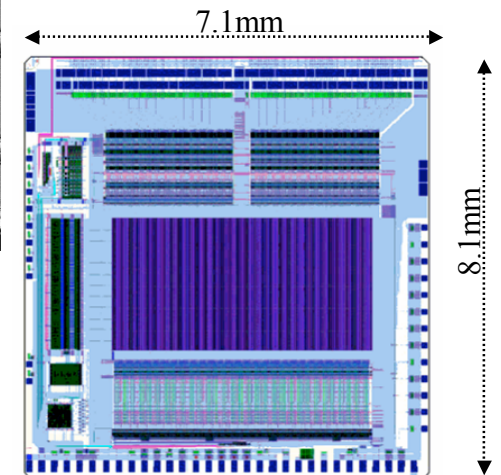
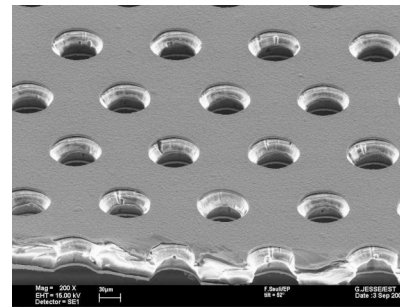
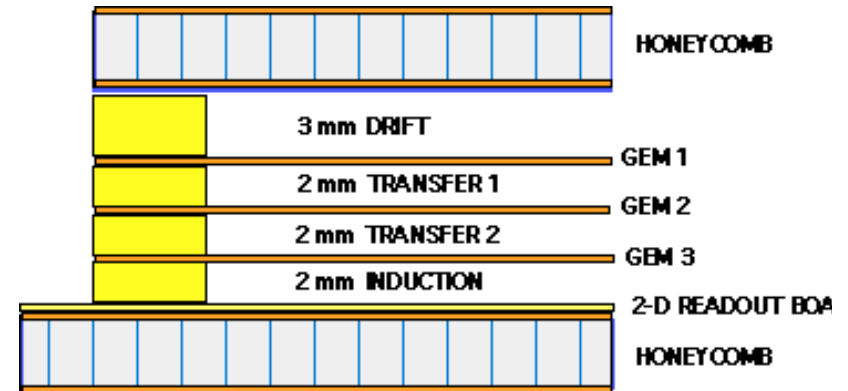
- Profit from experience by COMPASS with triple-GEM technology (fast, precise)
- Establish collaboration to a US company to develop and manufacture GEM foils
- Manufacture 2D-readout structures
- Design of readout system using existing chip: APV25-S1

- R&D team:

- Collaboration between STAR/PHENIX: ANL, BNL, MIT, Yale

- Tech-Etch Inc. (Plymouth, MA):

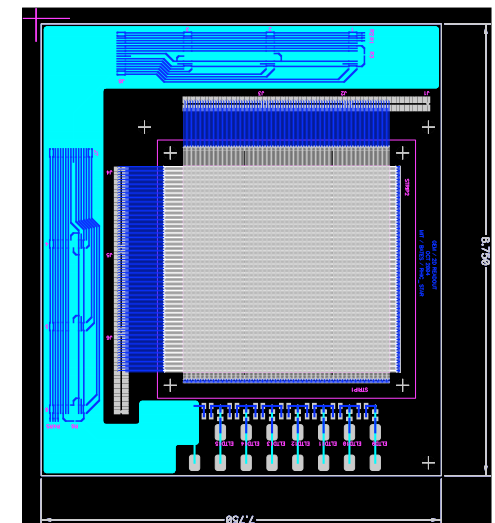
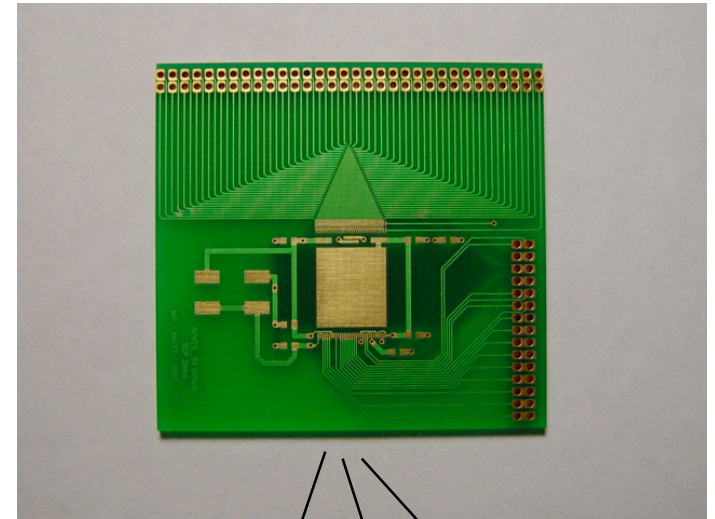
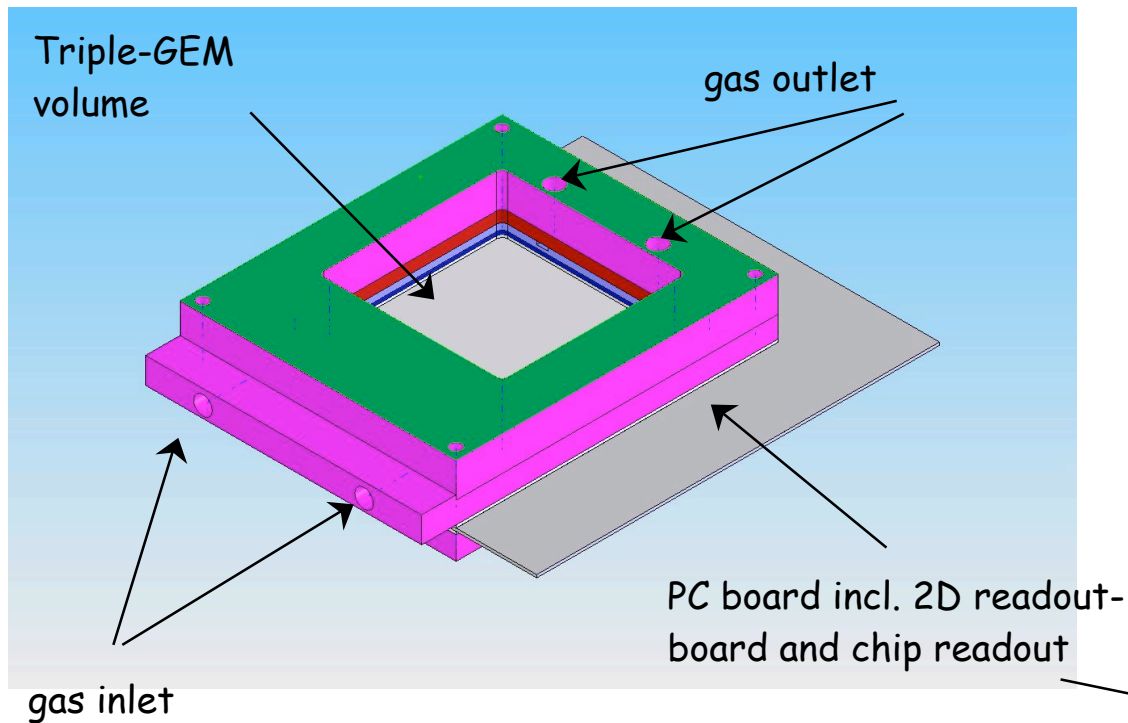
- TechEtch is capable of producing GEM foils
- First results are encouraging in terms of overall gain values achieved
- SBIR proposal to DOE from TechEtch in collaboration with R&D team: Submitted December 10, 2004



APV25-S1 chip

STAR tracking upgrade: R&D status

■ Triple-GEM prototype chamber



- ❑ 2D-readoutboard: Under preparation at Compunetics Inc.
- ❑ Hybrid: Available
- ❑ DAQ system: Under preparation
- ❑ Chamber mechanics: Under preparation

Cost estimate for STAR Barrel and Endcap Trackers

- Preliminary cost breakdown (Stage 1: barrel / Stage 2: endcap tracker)

Item	Design A		Design B		Remarks
	Amount	k\$	Amount	k\$	
Sensors	894	894	1392	1392	\$1000/sensor
Sensor R&D		100		100	\$50k times 2 types
Hybrids	260	130	464	232	\$500/beryllia substrate thin film
Hybrid R&D		50		50	
APV25 chips	4470	120	6960	174	\$25/chip
Cables	260	130	464	232	\$500/low mass cable
Cable R&D		50		50	
FEE	57 2160	600	890880	900	\$1/channel, in house R&D
Integration FEE/DAQ		100		100	
Power Supply		100		100	Power and bias supplies
Cooling		200		200	Under-pressure water cooling
Mechanics		1000		1000	Low mass, in house R&D
Misc. items		100		100	
Total		3574		4030	No contingency and overhead

Item	Disk design		Remarks
	Amount	k\$	
Sensors	675	675	\$1000/sensor
Sensor R&D		100	\$50k times 2 types
Hybrids	196	98	\$500/beryllia substrate thin film
Hybrid R&D		25	
APV25 chips	3370	85	\$25/chip
Cables	260	130	\$500/low mass cable
Cable R&D		25	
FEE	431360	450	\$1/channel, in house R&D
Integration FEE/DAQ		100	
Power Supply		100	Power and bias supplies
Cooling		100	Under-pressure water cooling
Mechanics		300	Low mass, in house R&D
Misc. items		100	
Total		2288	No contingency and overhead

Item	Disk design		Remarks
	Amount	k\$	
GEM chamber mechanics	200	100	\$500/chamber
GEM foils	900	180	\$200/GEM foil
Hybrids	728	364	\$500/beryllia substrate thin film
Hybrid R&D		25	
APV25 chips	1456	40	\$25/chip
Cables	260	130	\$500/low mass cable
Cable R&D		25	
FEE	186968	190	\$1/channel, in house R&D
Integration FEE/DAQ		100	
Power Supply		100	Power and bias supplies
Cooling		30	Air flow system
Mechanics		300	Low mass, in house R&D
Misc. items		100	
Total		1684	No contingency and overhead